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Hydro Geological Engineering and Geological Characteristics of the Upper Neretva Basin (Bosnia and Herzegovina)

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ABSTRACT

In the paper, a general overview of hydrographical-geomorphologic and geologic characteristics of terrain within the Upper Neretva basin, starting from a wider space of the inter-entity boundary line up to the source river zone, was given. On the basis of OGK: Kalinovik, Foča, Nevesinje and Gacko, a geological map of the river basin was made. According to tectonic structure, the terrain belongs to Zone of Mesozoic limestone and Palaeozoic schist, and the High Karst Zone. The tectonics of the terrain is complex. Along with the folded tectonics, radial tectonics is also expressed. Within the studied terrain, structurally-facial units are distinctive. Along with general characteristics, hydrogeologic and engineering-geological characteristics of terrain were presented as well, and the basic data on seismicity were given. Within the engineering-seismic research a calculation of parameters of seismic forces, at a level of the basic rock, was made. For the purpose of better understanding of hydrogeologic relations in the stream basin, and water abundance inside the specific section of the Neretva, a classification of rock masses and the river basin delimitation were performed. The boundary of river basin-water parting was determined on the grounds of analysis of geologic structure, geomorphologic relations and research of underground water connections.

By researching the hydrogeologic relations and characteristics of the included rock masses, it was determined that at the bottom of the Neretva valley (canyon), as well as on high sections of slope sides exist perennial and periodic intermittent springs of different abundance.

Keywords: *Hydrogeologic Characteristics, Engineering, Geological, Seismic, Basin Neretva*

1. INTRODUCTION

The Upper Neretva includes a section of the basin of this river upstream from town of Konjic. The Upper Neretva has been a subject of study several times since 1953, when a clear geological map 1:50 000 was made, as well as the basic project of water power development of Neretva and Rama. Geologic research continued in 1959 and 1960, and more extensive research for HE Ulog was finalized in 1965. Along with geophysical testing, minerological-petrological, paleontological and physical-mechanical explorations were conducted, as well as testing of the underground waters and delimitation of the river basins of the Upper and Lower Neretva in the area of Luk and Kruševkljani (Mountain Crvanj-Montenegro). Since 1986, an extensive research has been done within the project of the Upper Neretva, and in 1989 a conceptual project HE Glavatičevo was worked out. Within the extensive research, seismologic research was conducted as well. In later period, a conceptual solution for HE Ljubuča was reached and photo geological analysis of the structural-tectonic elements for the area from the source of the Neretva up to Mostar, was made. In addition, the Institute of Earthquake Engineering and Constructions of Banja Luka, in co-operation with the Institute of Seismology Sarajevo, had conducted dedicated seismological testing.

During these investigations, existing documents, sheets of the geological map Kalinovik, Foča, Nevesinje and Gacko, and attached explanations for these maps were used. Along with preparatory works, field and cabinet works were also performed on the preparation of documents. Within the fieldwork, recognition and geological mapping of accessible sections of terrain were performed in order to get a more realistic insight into geological and tectonic structure, as well as hydro geological properties of the rock mass.

In the paper, a geomorphologic and hydro graphic analysis of the Upper Neretva basin was presented, as well as geologic-tectonic structure and hydrogeologic characteristics of the mentioned river basin. On the basis of analysis of geologic structure and geomorphologic relations, as well as testing the underground water connections, a general delimitation of the river basin was performed.

2. HYDROGRAPHIC CHARACTERISTICS OF THE RIVER BASIN

The Upper Neretva is an upstream section of the course from the inter-entity boundary line up to source of Neretva. The river

basin of the Neretva up to the border covers approximately 500 km^2. From the river basin of Trebišnjica and the Lower Neretva it is separated by Crvanj, areas of Morina and Vučevo. The utmost southeast edge of the river basin is dominated by an area and notch of Čemerno. In this area a watershed was formed between the three river basins: Neretva-Drina-Trebišnjica. From river basins of the Bosnia and the Drina it was divided by mountain massifs of Treskavica, Lelija and Zelengora. The Neretva River rises under the Gredelj peak, southwest from Čemerno, in the form of headwaters which are formed by annularly arranged smaller springs and courses. Because of this, in the uppermost section it has a torrential character.
The Neretva with its valley stretches by middle section of the river basin, with a strike tending in a northwest-southeast direction. The change of direction on section Ulog-Ljubuča is conditioned by structural-tectonic relations.

The right tributaries of the Neretva are rivers of the Ljuta, the Jezernica (also Tatinac) and the Rijeka, and smaller tributaries are the Klištica, the Bistrica and other. More significant tributaries flowing into the Neretva from the left are the Jezernica, the Likač potok and the Živašnica. Of the mentioned tributaries according to water abundance the Ljuta and the Jezernica distinguish themselves, whereas the Ljuta and the Živašnica flow into the Neretva downstream from the inter-entity boundary line. Downstream from the inter-entity boundary line on the right valley side, in the side fossil valley an abundant Krupac well-spring was formed. This spring drains also a section of the river basin which belongs orographically to upstream water current of the Jezernica-Tatinac with the Vrhovinska River.

On both valley sides of the Neretva there are perennial and periodic intermittent springs of minor abundance, but the springs on the right valley side, at contact of flysch and carbonates are more abundant.

Among the lakes, glacial lakes of Jezero above Ulog, Štirinsko and Kotlaničko Lake on Lelija, Bijelo and Veliko Lake on Treskavica and Blatačko Lake on Lavnica should be mentioned.

3. GEOLOGICAL STRUCTURE OF TERRAIN

In river basin of the Neretva, the Mesozoic sedimentary rocks are predominant and tertiary sediments are less represented. Namely, the carbonate deposits of the Mesozoik are most common and somewhat less are represented the Mesozoic and Tertiary clastic sediments. Relatively high participation of the carbonate sediments in the structure caused the karstic features of this area. The Triassic sediments are most common, occupying the area of the river basin larger than 50 %. Of the Triassic sediments, the Cretaceous sediments that were found in central and southeast section of the river basin are less represented. These are followed, according to participation, by clastic and clastic-carbonate sediments of the Jurassic, whilst the Tertiary sediments and igneous rocks are insufficiently represented.

Geological map of the river basin was made on topographic basis 1: 100 000, by using the sheets of geological map; Kalinovik, Foča, Gacko and Nevesinje (Figure 1.).

In geological structure of the river basin, the following lithostratigraphic units are included:

Lower Triassic appears in two separate zones of the Dinaric strike. From north to south, these are:

- Vrhovina-Vlaholje-Jelašca Zone
- Ljubuča-Obalj-Štirinsko Lake zone

These are mutually separate localities, which can be generally divided into the zones.

In the northeast section of the river basin the first zone of verfen sediments was found, represented by micaceous quartz sandstone and schist, over which lie the middle Triassic limestones and dolomites, or transgrade the flysch sediments of the Jurassic. These sediments are more widespread in the area of Bistrica (the Drina river basin).

The second zone of Lower Triassic sediments stretches from east border of the river basin (Štirinsko Lake) toward northwest on several isolated lots. The sediments that are lithologically identical with those in the first zone are represented here as well. The oldest rocks of Lower Triassic are usually found in anticlinal sections of the structures as well as in tectonically arouse limbs of the particular dislocations. This means that Lower Triassic deposits were found at different altitudes of over 1500 m on Lelija, up to height of 500 m in Ljubuča.

Middle Triassic is developed predominantly in limestone and dolomite facies, whereas the elements of volcanogenic-sediment formation were sporadically found. The Anisian is represented primarily by limestone, dolomitic limestones and dolomites stratified in thick beds. The Ladinian is represented by limestone-dolomite facies, and sporadically in the Ladinian stage appears the complex of rocks formed by marl, argillaceous limestone, chert, igneous rocks and tuffs.

Middle Triassic-The Ladinian (T_2^2) is represented by relatively larger masses of igneous rocks: diabases and spilites (bbT_2) which are in the tectonic contact with carbonates or are interstratificated. They are bound with lower horizons of Middle Triassic (T_2^2). Diabases and spilites are the rocks of ofitic, fine-grained structure and massive texture. In process of decay, appear characteristic spherical forms dimensions of cm-m appear. Over these igneous rocks lie the attached association of the Ladinian stratified rocks: limestone, chert, sandstone, tuffs and marl, and at the highest horizon, the plate and stratified limestone with nodules and intermediate rocks of chert and chert. They are building the high sections of the left canyon of the Neretva in the area of Carevica spring, probably as the accompanying association, or are interstratificated into diabases.

The Upper Triassic was developed in limestone and dolomites.
Limestone-dolomite masses of the middle and upper Triassic predominantly participate in terrain structure of the river basin; therefore the karstic features of those masses have commensurately significant influence on hydrogeologic relations.

Over the middle and upper Triassic limestone and dolomites, and beneath the Jurassic – Cretaceous flysch are located the sandy and argillaceous limestones, with nodules and scarce intermediate rocks of chert and marl (The Triassic, Jurassic -T, J?).

In relation to the Triassic sediments, the **Jurassic** ones are relatively poorly represented and can be generally separated to limestone-dolomite and flysch facies.

Limestone-dolomite facies of the Jurassic deposits is prevalent in southwest section of the river basin in the area of Crvanj-Vučevo. This is where the Jurassic dolomites lie over Triassic ones and limestone as well. On some localities (Živašnica, Morina) appear lias, black limestone with marl and chert, whilst the other sediments of the Jurassic in the area of Crvanj and Morina are represented by limestone.

Flysch facies is in the area of Nedavić, Trnavica and in northeast section of river basin in the area of the Ljuta, under Treskavica. These sediments make a transitional zone from the Upper Jurassic to Lower Cretaceous, and are treated as Jurassic-Cretaceous flysch. They are represented by clastic sediments-sandstone, marl, calcarenites, breccia with limestone intermediate rocks, argillaceous limestone and chert nodules. In structure of the terrain that belongs to the Upper Neretva basin, these sediments are significant from hydrogeologic aspect and the function they have in the terrain. Thickness of flysch series is from 100 to 150 m.

The Cretaceous is represented by limestone and flysch facies. The limestone, Upper Cretaceous is represented by grey and bright limestone of Cenomanian-Turonian. Flysch Cretaceous is according to participation right behind the Triassic sediments. It can be found in the upper course of the Neretva from the source itself, crossing the Neretva between Gapić and Živašnica, bypassing the river curve and stretches in direction of northwest. Flysch sediments lie transgressively and discordantly on the Triassic, respectively the Jurassic sediments, but they are often in tectonic contact with them as well. They are represented by sandstone, marl, clay, calcarenites, breccia, argillacerous limestone, breccia limestone and limestone with chert. In this heterogenic series, five lithofacial packets are separated.

The first three are of argillaceous limestones, and the fourth and fifth represent the sandy –argillaceous (clastic) facies. Thickness of flysch deposits is very large, approximately 1200 m.

Cretaceous flysch, likewise the Jurassic-Cretaceous one, is important from hydrogeologic aspect and from aspect of water utilization.

Marly facies (^{4}K) It is formed most commonly of calcarenites and marl, and less of limestone, breccia, sandstone and clay. It lies over higher sections of limestone facies (^{3} K). Sequences are of considerably smaller thicknesses against the limestone development. They are mostly complete with intervals made of calcarenites, argillaceous limestone, marl and clay. This facies is intensively folded, for the most part around the border with ^{3} K. The folds are decimetric and most frequently upturned, with fall of the axial plain toward SI. The folds are of decimetric, as well as metric dimensions.

Cretaceous flysch-sandy facies (^{5}K) This element has all characteristics of clastic, respectively the sandy flysch. Sequences are made of sandstone with gradient stratification, then of sandy – marly limestone, calcarenites, marl and clay. This series is more intensively folded than ^{4}K. The folds are decimetric, seldom metric, most frequently upturned and broken, with inclination of axial plains toward SI.

The Neogene is present in the form of smaller and larger isolated lots. These are Argud, Hotovlje and Kalinovik. They are represented by coarse conglomerates and breccia, and at higher levels by sandy-argillaceous limestone, marl, less frequently clay and coal bands. These deposits are of small thickness, most frequently up to 50 m.

The Quaternary (Q) is represented by genetically and granulometrically different materials that make the covers of small thickness, but with relatively high widespreadness.
Significant are the blocks of sandy clay and clyey rock debris, locally united by sandy – argillaceous binder). Larger and more spacious mass of clayey rock debris and blocks are on the right riverside northward from Studenac. It is probably an old rockslide from the stage of carving the Neretva, later, partially levelled by fluvial erosion. Foundation failure concavity in the plateau was also registered.

Spatially larger masses (accumulations) of these materials are on the left riverside in the valley at contact of T_2^1 and T, J, in the Neretva itself, under Treskavac and downstream from Treskavac up to the inter-entity boundary line. In this area inactive and active landslide areas were registered, as well as active ditching. At the utmost JZ section of the map, on the left riverside, an active rock creep was formed and an active ditching process in T, J series of limestone with marl and chert was developed.

Alluvial deposit (al) In the Neretva riverbed itself a continual, actual, predominantly coarse crushed deposit was formed: gravel, lump, poorly rounded blocks and locally the coarse sand. Thickness of deposit in the extreme canyon section ('U') of the riverbed was determined by drilling and is up to 7 m. On the lowest terraces of the river within the flysch, coarse gravel and lump are represented, and on the terrain surface itself a thinner layer of sandy clay, sand and loam is present.

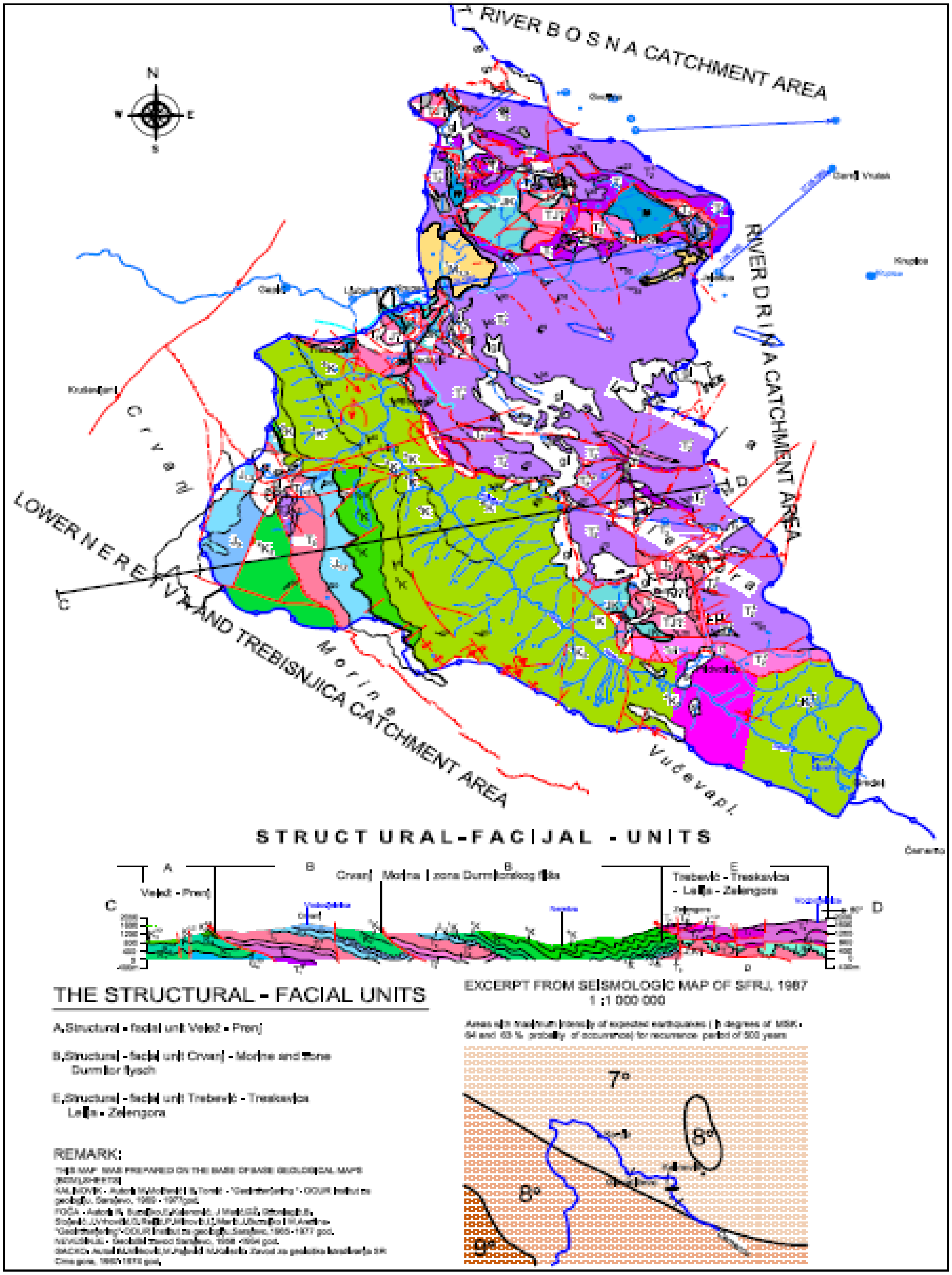

Figure 1. Geologic map with hydrogeological elements, geologic profile and seizmologic map (excerpt from seismologic map of SFRJ, 1987 1.1000 000).

LEGEND:

A. LITHOSTRATIGRAPHIC MARKS AND HYDROGEOLOGIC PROPERTIES

AGE		MARK	LITHOLOGICAL COMPOSITION	POROSITY TYPE	HYDROGEOLOGICAL FUNCTION	ENGINEERING - GEOLOGY CLASSIFICATION
QUATERNARY		al	ALLUVIJAL DEPOSIT;GRAVEL,SAND AND COBBLES	INTERGRANULAR	HIGHLY PERMEABLE ROCKS; AQUIFER, WATER BEARING BED AND STORAGE	NONCOHESIVE COARSE- GRAINED AND FINEGRAINED CLASTIC SEDIMENTARY ROCKS
		s	TALUS: DEBRIS ANA BLOCKS			
		u	ROCKFALLS: DEBRIS AND BLOCKS			
		j	TUFA			
		lgl	LIMNOGLACIAL SEDIMENTS: GRAVEL AND CLAY			
		gl	MORAINES:DEBRIS, BLOCKS AND CLAYS			
TERTIARY	MIOCENE	$^{1}M_{2,3}$	CONGLOMERATES, TUFACEOUS AND SANDY LIMESTONES	FRACTURE - FISSURE, SECONDARY CAVERNOUS AND INTERGRANULAR POROSITY	COMPLEX OF IMPERMEABLE AND PERMEABLE ROCKS, AQUICLUDE FUNCTION PREVAIL WITH THE GROUND	COMPLEX OF WELL TO POOR PETRIFIED AND LOCALY UNPETRIFIED AND LOCALY UNPETRIFIED CLASTIC ROCKS,
		$M_{2,3}$	CONGLOMERATES, TUFACEOUS SANDSTONES, SANDSTONES, MARLS AND CLAYS			
	PALEOGENE	Pg	CALCARENITES, BRECCIA LIMESTONES, SANDSTONES			
CRETACEOUS	UPPER	^{5}K	SANDSTONES, SANDY- MARLY LIMESTONE,MARLS, CLAYSTONES,CALCARENITES			
		^{4}K	CALCARENITES, MARLSTONE WITH SOME LIMESTONES, BRECCIAS, SANDSTONES AND CLAYSTONES			
		^{3}K	MARLY AND SANDY LIMESTONES, LIMESTONES, MARLSTONE AND CALCARENITES			
		^{1+2}K	BRECCIAS, BRECCIA LIMESTONE, CALCARENITES, MARLY LIMESTONES, MARLSTONE AND CLAYSTONES			
		$K_2^{2,3}$ $K_2^{1,2}$	LIMESTONES WITH CHONDRODONTAE AND RUDISTS	FRACTURE - CAVERNOUS	IMPERMEABLE ROCKS WITH FUNCTION OF AQUIFER	COHESIVE WELL PETRIFIED CARBONATE ROCKS
	LOWER	K_1	LIMESTONES WITH TINTINNIDS, SOME DOLOMITES			
JURASSIC	UPPER	J,K	FLYSCH;BRECCIAS, BRECCIA-LIMESTONE, MARLSTONE, SANDSTONES, CLAYSTONES, CALCARENITES	FRACTURE - CAVERNOUS	H.G. COMPLEX WITH FUNCTIN OF A QUICLUDE	COMPLEX OF COHESIVE WELL TO POORLY PETRIFIED SEDIMINTARY ROCKS WITH CARBONATE BONDING AGENT
		J_3	LIMESTONES AND SOME DOLOMITES	FRACTURE - CAVERNOUS	PERMEABLE ROCKS WITH FUNCTION OF AQUIFER	COHESIVE WELL PETRIFIED CARBONATE AND SILIFICATED ROCKS, LOCALLY VOLCANIC ROCKS
	MIDDLE	$J_{1,2}$	LIMESTONES, DOLOMITES, CHERTS, MARLSTONE			
		T,J	LIMESTONES WITH CHERTS AND MARLSTONE	FRACTURE - FISSURE	LESS PERMEABLE ROCKS	
TRIASSIC	UPPER	$T_3^{2,3}$	LIMESTONES AND DOLOMITES	FRACTURE - CAVERNOUS	PERMEABLE TO LESS PERMEABLE ROCKS AQUIFERS	
		T_3	DOLOMITES AND DOLOMITIC LIMESTONES			
		T_{2+3} $T_{2,3}$	DOLOMITES, DOLOMITIC LIMESTONES CHERTS DOLOMITES			
	MIDDLE	T_2^2	CHERTS,SANDSTONES, CLAYSTONES, TUFFA,, LIMESTONES AND DOLOMITES	FRACTURE - FISSURE	LOW PERMEABLE AND IMOERMEABLE ROCKS AQUICLUDES	
		[illegible]	DIABAS,SPILITE			
		$T_2^{1,2}$ T_2^1	RED BRECCIA - LIMESTONES, LIMESTONES AND DOLOMITC LIMESTONES	FRACTURE - CAVERNOUS	PERMEABLE ROCKS AQUIFERS	
		T_2^1	DOLOMITES			
	LOWER	T_1^2 T_1	MARLSTONE, SANDSTONES, CLAYSTONES, MARLY SANDY LIMESTONES	FRACTURE - FISSURE	IMPERMEABLE ROCKS AQUICLUDES	COMPLEX OF POORLY TO WELL PETRIFIED CLASIC ROCKS SECONDARULY CARBONATE ONE

Figure 1 a. Legend (litostratigraphic marks and hydrogeologic properties)

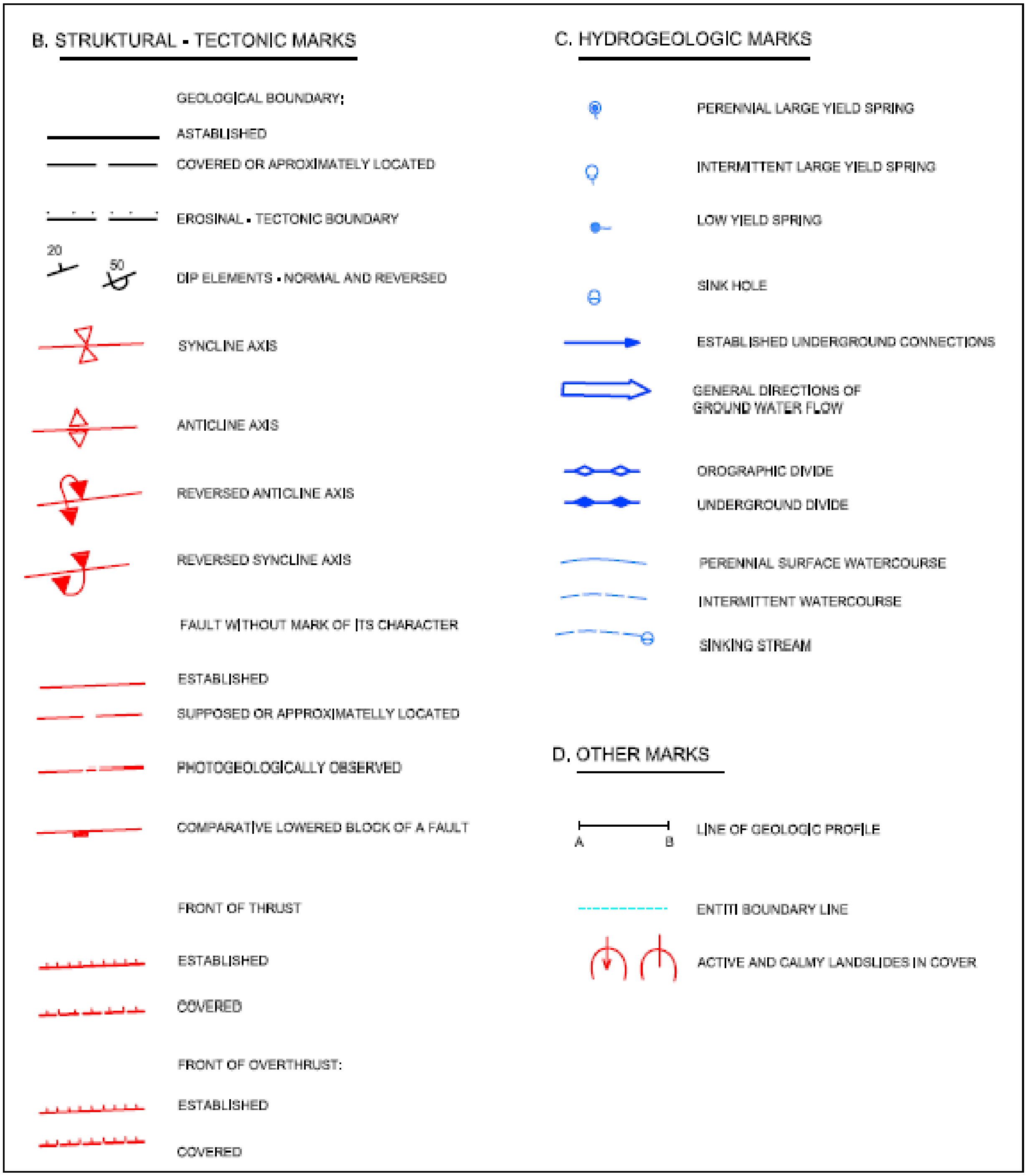

Figure 1b. Legend (structural-tectonic marks and hydrogeologic marks).

Proluvial deposit (pr) of heterogenic structure forms water coning at the mouths of all tributaries. Material originates from higher sections of stream valleys where the ditching and rinsing processes are intensive. This should be considered during the planning and execution of antierosion works and protection of accumulation against filling up.

Eluvial-deluvial (e, d) covers, as well as colluvial deposits of inactive (ku) landslides are made of clayey rock debris, sandy clay and rock debris. Spatially larger and thicker deposits are present over the dam on the left riverside (e, d) on the locality of Ljeskovica. On the left riverside of Paleški stream there are larger accumulations of argillaceous – rock debris material within a partially active landslide area. Upstream from the partition spot, these materials are largely present.

4. TECTONIC STRUCTURE OF TERRAIN

Tectonics of the terrain is complex and complicated. According to tectonic structure the terrain belongs to „Zone of the Mesozoic limestone and Paleozoic schists and the High Karst Zone (Figure 1.). Within the studied terrain, the following structural-facial units can be distinguished:

- The Crvanj-Morine Unit with Durmitor flysch is the most important for this region. There are the Triassic and Jurassic sediments (limestone, dolomites and sediments of Cretaceous flysch) in the structure. Toward northeast, this zone lies over the line Ljubuča-Pridvorica under Durmitorska navlaka.
- The Bjelašnica-Visočica Unit is made of dolomites and limestone of the Middle and Upper Triassic and is positioned on Crvanj-Morine Unit, beyond the river basin area on SZ.
- The Turovi-Bare-Kuti-Dumoš Unit spreads in the area of Treskavica, Lelija, Zelengora and Nedavić. It si made of the Triassic, Jurassic and Jurassic -Cretaceous carbonates of clastites and less of igneous rocks.
- The Trebević, Treskavica-Lelija-Zelengora Unit is composed of the Lower and Middle Triassic clastites and carbonates. It is positioned on the Crvanj-Morine Unit in JI section of the river basin.

Structural-facial unit of Crvanj-Morine with Durmitor flysch zone is the most significant, because it stretches in the middle of this area where the Neretva cuts its riverbed. The Cretaceous flysch is folded into folds of hectrometric sizes, and toward northeast near Durmitorska navlaka the flysch is folded in a few folds of decimetric and metric sizes.

The folding is expressed in the Triassic, Jurassic and cretaceous sediments. In addition to folding tectonics, radial tectonics is also expressed. Besides longitudinal faults, which make reverse fault lines between the tectonic units, there are normal faults as well, with parallel, diagonal and vertical strikes of direction on the Dinaric directrix. Large blocks of terrain are separated by these faults. Among these, the most significant faults are the fault of Jezero-Obrnja and the fault Trešnjevica-Strane, along which the Triassic and Jurassic carbonates and clastites with Cretaceous flysh are in contact.

Tectonic movements in this area were developing in several stages. Major folding occurred in the beginning and at the end of the Upper Cretaceous, when the High Karst Zone was mildly folded and overthrusted in the northeast by formations of these areas with rising and folding. By additional tectonic movements, probably at the end of the Eocene or in the Oligocene folding and reverse-fault occurred also in the High Karst Zone, but these reverse-faults occurred also in the northeast areas, as these masses cover the Paleogenic sediments as well. Further fragmentations formed depressions in which Neogenic sediments were deposited, while vertical movements at the end of the Neogene and Quaternary lifted these areas and turned them to high mountains. Further floor heaves during Quaternary caused forming the canyon of the Neretva, the Ljuta and other rivers.

5. HYDROGEOLOGICAL CHARACTERISTICS OF TERRAIN AND BORDERS OF RIVER BASIN

The river basin of the Upper Neretva was made of rock masses which differ according to their hydrogeologic characteristics and functions. Terrain in the river basin of the Upper Neretva was made of different hydrogeologic categories of rock masses, as follows:

- hydrogeologic collectors of crack-cavernous porosity, extremely water permeable,
- hydrogeologic collectors of crack-cavernous porosity, poorly water permeable ,
- complex of hydrogeologic collectors and isolators of crack porosity-watertight to permeable to water,
- hydrogeologic isolators of crack porosity-watertight

Hydrogeologic collectors of crack-cavernous porosity are represented by limestone and dolomites of Triassic, Jurassic and Upper Cretaceous, which can be regarded as the rocks well permeable to water, in which underground waters move in the concentrated underground channels. These are, at the same time, major masses in the terrain within which underground waters are accumulated, whose draining is being done through karst springs that are characteristic of specific contact zones, respectively for erosion basis of the Neretva River. These rock masses occupy a relatively vast area giving karst hydrogeologic characteristics to the areas of Treskavica, Lelija and Zelengora, then Crvanj with intermediate space.

If within the Triassic rocks the Ladinian sediments or diabases appear as well, then in such parts the karstification process is slowed down, or stops there depending on the structure of these deposits. Then these deposits can do the function of side barrier or floor isolators.

Hydrogeologic isolators of crack porosity, practically watertight, are represented by clastic sediments of the Lower Triassic, and by flysch deposits predominantly of marly-sandy structure (the Jurassic-Cretaceous and upper Cretaceous flysh) and Tertiary sediments.

The Lower Triassic watertight rocks, in the basis of which are the Paleozoic slate-sandy complex is a floor hydrogeologic isolator in this terrain, whose hydrogeologic function is very important. The other factors such as regime and direction of movement of underground waters, and other characteristics of collectors, appearances of discharge areas of ground water and other depend on position of these sediments, structural form and relations to hydrogeologic collectors and hypsometric relations of these masses. Supported area of these sediments represents, at the same time, the basis that can be reached by karstification process within the Triassic carbonate complex lying above.

Sediments of the Senonic flysch in marl and sandstone facies can also be grouped into hydrogeologic isolators, as well as tertiary sediments which are most frequently of small thickness and in given relations in the terrain are commonly represented by overlaying hydrogeologic isolators.

Complex of hydrogeologic collectors and isolators is represented by carbonate-clastic Cretaceous flysch with zonal interchange of these masses, as well as sediments of volcanogenic-sedimentary rocks of Middle Triassic. Such complexes of sediments with alternating hydrogeologic functions can be deemed relative, but also a complete isolator against the pure limestone-dolomitic masses.

Geologic relations and hydrogeologic characteristics and functions of rock masses caused in given climatic conditions an uneven influx of waters into water current of the Neretva along the observed section of course. So, for example, in the course upstream from Nedavić, karst springs appear high by the right side of the valley, at the contact of limestone collector and flysch Cretaceous sediments, in the form of barrier springs, whose capacity is reduced during summer and autumn. These springs are supplied by water from the area of the Dumoška Mountain and Zelengora.

Anticline of Lelija with verfenic schists in the core influences the division of waters from this sector to waters from upper section and those that tend toward the area of Nedavić-Ljubuča, i.e. in the area of large curve of the Neretva. In this downstream zone, significant karst springs concentrated on relatively small section appear. These are the following springs: Krupac, Crnoglav, Buk and Srijemuški Do. Among these, Krupac is the most significant spring (Q = 5-20 m^3/s), and the other ones often reduce the quantities or dry up during a dry, summer season.

Toward these springs flow the waters from the mountain hinterland of Lelija, as well as from area of Kalinovička Zagora, which is proved by colouring.

Among more significant occurrences in the hinterland of this zone northward, are the springs of the Ljuta and Vrhovina, at contact of the Jurassic-Cretaceous flysch and the Triassic limestone, or the Lower Triassic schists and Triassic limestone of Treskavica (Vrhovina).

Watershed of the Upper Neretva is conditioned by geologic structure, i.e. mutual relations of hydrogeologic isolators and collectors and it has, on a large section, a character of underground zonal watershed.

On the section Krupac-Crvanj-Morine-Vučevo, watershed is within limestone-dolomitic and marly-sandy complex and is thought to correspond to orographic border with possible minor declinations, as well as the area of headwaters of Neretva.

The northern limit of the river basin toward the river Željeznica is partially orographic, on the saddle Hojta, made of flysch rocks (J, K) and on plateau of Treskavica this limit is an underground zonal watershed. With regard to high position of floor isolators on northern slope of Treskavica, it is thought that larger part of this area belongs to the Neretva river basin. Eastern, karst part of Treskavica (Gvozno polje), belongs to the Drina river basin.

By testing of limestone sink in Gvozno polje, underground connection with the spring in the Bistrica valley (the Drina tributary) was determined. On the section Kalinovička Zagora the frontier of river basin has a character of underground zonal watershed. Division of river basin was made on the basis of results of colouring the limestone sink.

The limestone sink on the Tatinac in Kalinovik is connected underground with Krupac spring at the mouth of the Ljuta, and the limestone sink in village of Jelašac with the springs of Krupica and Vrutok in Bistrica valley.

In the area of Lelija and Zelengora, a border of the river basin is also an underground zonal watershed, and the high position of the Lower Triassic floor isolators in area of Govze and Džafer potok conditions the movement of larger part of water from this area in direction of the Neretva. Testing of the limestone sink in surrounding of Štirinsko Lake, where a connection with springs in the Neretva valley (Klištica) was determined, contributed to delimitation of accompanying waters.

Surface of contoured basin of the Upper Neretva up to profile 'Inter-Entity boundary line 'is P=approx. 500 km^2 and Q_{sr}=15m^3/s.

Within the separated basin of the Upper Neretva up to inter-entity boundary line, in its northeast section (wider area Kalinovik–Obalj) is situated, at the same time, the area of common basin of spring Krupac and the Upper Neretva (Figure 1). Reasons for standing out are yet to follow. By colouring the limestone sink in water course of the Tatinac River, an underground water connection with Krupac spring was determined. The Tatinac and the Vrhovinska River flow into the Jezernica, whose river basin area is entirely within the orographic river basin of the Upper Neretva. This means that underground streams from the Tatinac, and, at the present level of understanding the problems, possibly from some other water courses, gravitate underground toward Krupac. Krupac spring is characterised by large and relatively equalized abundance and according to available data Q=5-20 m^3/s. The fact is that orographic basin of Krupac is only around 0.75 km^2.

In conditions of saturation of the subterranean karst, surface circulation in the Tatinac is also being established and waters flow into the Neretva through the Jezernica, upstream from Krupac.

On the grounds of the exposed and considering the available hydrogeologic elements, it is estimated that from approximately designated common basin, the waters are directed into two zones: through limestone sink underground toward Krupac and surface water courses, when flowing is established, upstream from Krupac to Neretva.

So, the hydrogeologic basin, respectively the water balance up to the profile ‘Inter-Entity boundary line‘is smaller, to a certain extent, than the outlined river basin area. These, in general features mentioned problems, should be a subject of more detailed research if their necessity and appropriateness are estimated.

6. SEISMOTECTONIC CHARACTERIISTICS OF THE BROADER AREA

The broader area of Glavatičevo is located in the boundary zone of the External and Central Dinarides. Similar to other sections of Dinarides, previous geologic research has shown that the basic forms appeared here also during the continuous tectogenesis of the Middle Alps epoch (Arsovski, 1982). Processes of folding and faulting started in the Laramian orogenetic phase and lasted until the end of the Oligocene; so that this area is characterized by the presence of first and second order fault structures.

Within the earthquake engineering- research, a calculation of parameters of seismic forces at the level of basic rock was made, by defining the maximum regional earthquake. In addition, basic data on terrain seismicity within the upper Neretva basin were given.

Assuming that the expected earthquake has M = 6.3 and that it is 20 km far from the location, average values of earthquake parameters, at the level of basic rock, were derived:

$a_{max} =$ 0.185 (g)
$v_{max} =$ 18.47 (cm/s)
$d_{max} =$ 8.89 (cm),

Basic level of seismicity is $I_{max} = 7.5^0$ MCS

On the grounds of the performed analyses the resulting seismic parameters on basic (solid) rock, Cretaceous flysch, the expected maximum horizontal ground acceleration, a^0 max, and maximum earthquake intensity Imax (elements of seismic hazard) were presented, in numerical form, for the five mentioned return periods, with probability of 70%, in the following table .

Table 1. Seismic Parametres on Basic Rock

Seismic parameter	Return period of time (year)				
	50	100	200	500	1000
a^o_{max}[%g]	6.6	8.2	9.,5	10.4	11,9
I_{max} [MSK-64]	6.5	6.7	6.9	7.00	7.2

According to seismological map of SFRJ from 1987, the maximum expected earthquake intensity in the subject area is 7^0MSK-64 scale and probability of occurrence of 63% for 500 years return period. This means that maximum earthquake of 8^0 MSK-scale may be expected for the mentioned return period.

7. ENGINEERING-GEOLOGICAL CHARACTERISTICS OF TERRAIN

In the canyon section of the river, downstream from the mouth of Likač potok, middle Triassic (Anisian) limestones, Triassic-Jurassic limestones with chert and diabases are represented. Triassic limestones are solid but also the fissured rocks of the crack cavernous porosity, which form hypsometrically the high sections of the right valley side of the Neretva.

The Anisian, mostly thick-bedded and massive limestones make a more favourable and better environment from the engineering-geological aspect, in relation to diabases and the Triassic-Jurassic plate-to-stratified limestones. In the fault zones they are intensively cracked and degraded, which conditions the rockslide occurrence and the rock creep forming. Carbonate and clastic rocks of the Cretaceous flysch form the valley of the Neretva, starting from a mouth of Likač potok up to the source zone of the river under Gredelj.

Sandstone, sandy-argillaceous limestones, calcarenites, marl and clay from the Cretaceous period (^5K) form the terrain section starting from the downstream contact with the Triassic carbonates, then further upstream towards a mouth of the right tributary of the Valovitac. Thickness of series is estimated to about 400 m. The series is of secondary folding, and the folds are frequently upturned, with a fall of axial plain toward SI. These rocks are susceptible to disintegration, rinsing and ditching. In argillaceous rock debris covers landslides are formed as well. According to depth, they can capture also the basic rock mass during unfavourable lowering of layers. At the mouths of tributaries to the Neretva, water coning is formed. The left valley side of the Neretva is, to a certain extent, more susceptible to instability occurrences of the right side due to unfavourable lowering of layers.

Argillaceous package of thickness 300m, made of calcarenites and marls, has the same structural-textural characteristics, while argillaceous carbonates, breccia, sandstone and marls are less presented. Thickness of the package is up to about 300 m. From engineering-geological aspect, the terrain which is formed by rocks from this package is generally more stable and favourable for construction of the buildings. It participates in the structure of hypsometrically higher sections of the left valley side of the river.

In downstream section of the concerned area, where solid carbonate rocks are dominantly represented, engineering-geological complex of the well-bound and weakly stony carbonate, clastic and igneous rocks of the Triassic and Jurassic is also represented in the structure. Carbonates and dolomites, chert, marl, clay, tuff, sandstone, argillaceous limestone as well as partings of diabases and spilites are represented. To this complex belong also verfenic sandstones, clay, marl and limestones in the zone of Tvrda gora – Nedavići.

This complex has similar engineering-geological characteristics as the flysch complexes, which means that thicker packages of limestone have „reinforcing "role in terrain stability. Active and inactive landslides were registered, as well as ditching in the cover of depth over 2 m. Terrain sections which were formed by the bound well stony rocks are generally stable and represent a favourable work environment. However, terrain sections made of complex of different lithological rock types generally make the terrain a more unfavourable–weaker natural construction and work environment compared to previous group of rocks.

River basin areas and underground zones, from which the waters circulate towards the Neretva and the springs, are located in the regions of high mountain edges, which was partially proved by testing of underground water connections.

8. CONCLUSIVE CONSIDERATIONS

The river basin of the Neretva up to the Inter-entity boundary line, upstream from the Krupac spring, includes south part of Bosnia and northern part of Herzegovina. It belongs to mountain regions and is confined with high mountain reefs and surfaces from the surrounding basins. These are high mountains reaching the heights around 2000 meters. The river basin area was predominantly made of the Mesozoic sedimentary rocks, while the Neogenic sediments and igneous rocks take only an insignificant part in the structure of terrain. Regarding lithological structure, carbonate deposits are represented in largest numbers, followed by clastic sediments, and other rocks are far less represented.
Tectonic relations of this terrain are complex and complicated. Terrain belongs to two large tectonic units: Zone of the Mesozoic limestone and the Palaeozoic schist, and High Karst Zone.

With previous geologic research within the river basin area of Upper Neretva basic characteristics have been determined and delimitation of the river basin area was made. The river basin area was made of rock masses, which differ according to hydrogeologic characteristics and functions within the terrain. The boundary of river basin-water parting was determined on the grounds of analysis of geologic structure, geomorphologic relations and research of underground water connections. Water parting of the Upper Neretva is conditioned by geologic structure i.e. mutual relations of hydrogeologic collectors and isolators and it has, on a larger section, a character of underground water parting

Research on edges of basin should be conducted in future on Crvanj, Zelengora, Lelija and Treskavica. Namely, testing of new places where a river sinks into the earth and more detailed research on the basis of new data of the geologic map would enable further clarification of still open issues regarding the basin area, such as the problem mentioned herein, as well as more correct determination of basin area of the Krupac spring.

By researching the hydrogeologic relations and characteristics of the included rock masses, it was determined that at the bottom of the Neretva valley (canyon), as well as on high sections of slope sides exist perennial and periodic intermittent springs of different abundance. Within the series of flysch deposits and verfenic clastites there are springs of small abundance. However, in the canyon section from Nedavić up to Ljusić, there are several springs of different abundance. On the grounds of the exposed it can be concluded that there are more realistic possibilities for drinking water supply.

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